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ABSTRACT

This document chronicles a project called Model Nets, which studies the characteristics of computer networks that have a positive impact on K-12 learning. Los Alamos National Laboratory undertook the study so that their recommendations could help federal agencies wisely fund networking projects in an era when the national imperative has driven schools to be wired to the information superhighway. The study involved assembling and training site visit teams, conducting three-day site visits to schools across the country selected for their pervasive use of networks, and conducting surveys and focus groups of teachers at those districts. Combining descriptive data and survey data yielded a set of guidelines regarding the technical infrastructure of the ideal network, policy and implementation issues, and teaching and learning practices. The study found that even though school districts are still struggling to define appropriate and productive uses for these networks, the networks are sparking motivation among students and teachers. Many networks were obtained for administrative use and expanded for classroom use. Four out of five networks in the study were purchased "a priori," because they were perceived as a "good thing," not necessarily in light of particular educational goals. Recommendations for future research include a study on how networking affects student achievement. (BEW)

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Characteristics of Effective Networking Environments

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Introduction:

Model Nets was a national study of the characteristics of computer networks that positively impact teaching and learning in grades kindergarten through 12 (K-12). For the purposes of this study, we defined "positive impact" to be uses of a network that support a discovery-based and student-centered model of learning in which students explore, discover, and create, propose explanations and solutions, and take action on what they have learned. This model influenced the study design and methodology.

The Model Nets study originated approximately two years ago to address needs expressed by a consortium of federal agencies responsible for funding networking projects. The agencies included the Department of Energy, Department of Education, National Science Foundation, Department of Commerce, Department of Agriculture, National Aeronautics and Space Administration, Advanced Research Projects Agency, and the National Institutes of Health. Responding to a national mandate to network all schools, the consortium voiced interest in identifying criteria they could use to select the best and most appropriate projects. They also felt they had little information about successful scale-up and expansion of existing network environments.

Los Alamos proposed a study, subsequently funded by the Department of Energy, that would be sufficiently wide in scope to develop and support recommendations about how federal agencies can make the most effective use of taxpayers' dollars in funding networking technology projects in K–12 schools. We designed the study to identify and describe those characteristics that either enhance or create obstacles to implementing effective computer networking in schools. Using the data collected during the study, we developed a set of guidelines for implementing effective computer networks. These guidelines can help federal agencies in making funding decisions related to networking technology projects in K–12 schools. The guidelines also will be useful to school districts as they plan and implement computer networks.

With several factors in mind based on the needs of federal agencies and of school districts, we set out to design a study that would

- incorporate previous research about effective use of computer networking in school districts
- draw upon the computer networking knowledge of a team of experts in network technology and education
- incorporate site visits comprising interviews, focus groups, observations, and document reviews to examine a large, diverse set of districts across the country using computer networks

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- conduct a survey of all teachers at the districts in the study to determine their use of computer networks and to complement the findings of the site visits

We conducted the study in three phases:

- Phase I: Planning the Study. This phase included reviewing literature and previous research, forming a project planning team, developing data-collection instruments, and piloting the instruments and approach to site visits.
- Phase II: Collecting the Data. This phase included assembling and training site visit teams, conducting three-day site visits to school districts across the country, and conducting a survey of teachers at those districts.
- Phase III: Synthesizing, Analyzing, and Reporting the Data. This phase included distilling effective practices from site observations and survey responses, writing the report, and creating the guidelines to effective practice.

By complementing descriptive data from the observational site visits with survey data, our methodology provided us with qualitative and quantitative data from a number of perspectives about characteristics of computer network use in school districts. We synthesized this data within the three domains that framed our study: technical infrastructure, policy, and teaching and learning. Based on this synthesis, on the collective knowledge and judgment of our experts, and on the findings of previous research, we compiled the characteristics of effective practice into a set of guidelines. We also developed a list of the barriers that inhibit effective networking.

We centered the observational aspect of our field study on site visits to a national sample of public school districts making widespread use of computer-based networks, as determined by the 10 regional education laboratories (RELs) of the Department of Education. We focused on districts as our unit of analysis for two reasons: (1) we sought to understand the impact of wide area networks (WANs), a technology that transcends individual school use and is best suited to multiple, physically separated sites, and (2) decisions about policy and funding—two important components of network implementation—are generally made at the district level. In the 10 RELs' regions, we selected a sample of sites that represent a range of economics, geography, and demography. Model Nets research teams conducted visits to 32 districts and a sample of 93 schools within these districts. It should be noted that as the site visits proceeded, we saw considerable variation among districts in their degree of network implementation. This gave us an ideal opportunity to learn more about how schools overcome inherent barriers and constraints in expanding the use of their networks.

During each site visit, the site visit teams interviewed staff, conducted focus groups, observed education practice and facilities, and reviewed existing documentation to collect data from teachers, students, technology coordinators, administrators, and community members. The teams also collected previously distributed written surveys of teachers at each of the schools they visited. Finally, the teams wrote descriptive case studies of the sites, describing the three domains of each site's networking approach that framed our study: the networking technology infrastructure, policy issues concerning the development and use of the network, and teaching and learning practices using the network.

Throughout the study, Los Alamos engaged in several major partnerships, including those with the University of California–Los Angeles Center for the Study of Evaluation (UCLA), the Department of Education through its Regional Education Laboratories, and Boyer & Associates. UCLA assisted in the design of the study, administered the teacher survey and analyzed the survey data, and participated in Phase III.

The collaboration with the RELs represented one of the first major initiatives between the Department of Energy and the Department of Education under a newly signed memorandum of understanding by the Secretaries of both agencies. The RELs drew upon their relationships with state departments of education, school districts, colleges of education, and other groups in their regions to select sites and site visit teams for their regions. Representatives from the RELs also participated in the data analysis activities of Phase III.

Boyer & Associates facilitated the training for the site visit teams, assisted with supervision of the data collection, and participated in Phase III.

Guidelines to Implementing Effective Computer Networks:

We have created the guidelines for implementing effective computer networks on the following pages to assist federal agencies as they develop criteria for awarding funds to school districts implementing networks. The guidelines are also intended to help school districts to plan and implement computer networks. We derived these guidelines, or characteristics of effective computer networking, based on our case studies of school districts, on teacher surveys, and on the expertise of a group of subject-matter specialists who reviewed the research results.

For the purposes of the guidelines, "effective practices" are defined as those characteristics of computer network implementation that support a model of learning in which students explore, discover, create, propose explanations and solutions, and take action on what they have learned. The guidelines are not intended as an all-inclusive or rigid set of requirements. We do not expect even an exemplary school district to demonstrate every effective practice in these guidelines. We also recognize that many districts that were not included in the Model Nets research have developed other effective practices not mentioned here.

We have organized the effective practices under the three domains of our study: technical infrastructure, policy, and teaching and learning.

TECHNICAL INFRASTRUCTURE CHARACTERISTICS AND PRACTICES

Infrastructure

1. District provides convenient access to all users.
2. In a given school building, a single LAN supports video, voice, and data for both instructional use in all classrooms and administrative use.
3. In a given district, a single district-wide WAN supports video, voice, and data for both instructional and administrative uses.
4. District WAN has multiple connections to Internet.
5. District provides users with dial-up access from home through external Internet service providers.

Security

1. Configuration-control software prevents users from "hacking" individual computers and thus rendering them incompatible with the network.
2. Proxy servers and firewall technology limit access to sensitive information, as appropriate.

Services

1. All students, teachers, staff, and administrators have e-mail and share a common, districtwide e-mail system, which may include bridges between subsystems.
2. A shared, standardized network infrastructure serves all facets of education, including administrative and teaching functions.
3. The network supports a wide range of functions, including e-mail, file sharing, printer sharing, conferencing, access to productivity software (e.g., data bases of student information), news groups, terminal connections, access to library databases and CD ROM databases, access to the Internet and World Wide Web, security and climate-control systems, etc. (See Appendix E, Technical Infrastructure Requirements for Network Services.)

Support

1. A key server system provides centralized software distribution and configuration management.
2. Use of configuration control software (At Ease, FoolProof, etc.) helps support staff to maintain the network.
3. The district establishes baseline standards for hardware and software across the network to ensure compatibility and performance.

4. The district provides support in layers (for example, local or site level, district level over the network or by phone, and local visits).
    - District builds a cadre of internal (school and district) experts
    - District provides on-site network managers at building level
    - Students at high school provide "help desk" support to users and get vocational credit

POLICY AND IMPLEMENTATION CHARACTERISTICS AND PRACTICES

Vision, Leadership, and Decision Making

1. The vision of computer network use is integrated with teaching and learning and includes these components:
    - Universal access to the network by teachers and students
    - Network perceived as a tool
    - Improvement of instruction
2. Strong administrative support contributes to survival of vision as funding decisions are made.
3. One person championing the cause helps a network to succeed, but the champion need not be a manager or in position of authority. Important functions include lobbying for support, fundraising, and identifying resources.
4. Decision-makers support the vision.
5. Decision-making is shared between district and schools. Some decisions are best made centrally at district level to ensure compatibility among schools. However, schools are best able to determine their individual needs.
6. Districts maintain consistency and integrity of vision and plan. Funding or other opportunities are pursued only if they help the district accomplish their overall educational goals and objectives.

Planning

1. Plan integrates computer networking with district's overall strategic plan and with individual school plans. The computer networking plan links a set of achievable, long-term and short-term goals to the vision. It also provides the basis for proposals for funding.
2. Plan provides all schools with a step-by-step guide book documenting how to implement a computer network at the site level and how to gracefully expand and upgrade the network.
3. The plan is multifaceted and includes the following considerations:
    - Addresses educational goals and integration with curriculum.
    - Addresses technical support for users, including training on software and hardware.
    - Addresses professional development, with incentives to participate.
    - Addresses access for students.
    - Provides time for teachers to plan instructional use, train on networking, and explore network capabilities.
    - Is informed by needs assessment.
    - Provides for a sustainable network, with adequate budget; staffing; and provisions for the development, maintenance, and trouble-shooting of technical infrastructure.
    - Addresses selection of infrastructure components based on reliability and performance of network, in addition to cost considerations.
    - Identifies strategies to communicate the plan.
    - Defines roles and responsibilities of staff and students.
    - Involves stakeholders, including parents and community members, in planning process, so that they will understand the impact of computer networks, help define the use of networks for their district, and agree upon networking goals and objectives.
    - Involves computer network experts and technology coordinators from schools and district in planning process.

- Establishes integration of network with curriculum.
- Links use of computer networking to district-defined goals for student achievement.
- Addresses articulation across grades and across disciplines.
- Provides benchmark through evaluation plan for measuring progress and effectiveness of network implementation in relation to student learning.

Operational Policies and Implementation

1. Acceptable use policies govern activities of students and staff on the network.
2. Teachers receive written procedures related to such network issues as use, misuse, technical support, etc.
3. District provides network access to teachers, students, other school staff, parents, and community members.
4. District provides network access to students during non-class hours (lunch, free period, before and after school, etc.).
5. Students are encouraged to use the network outside of school for non-educational purposes.

TEACHING AND LEARNING CHARACTERISTICS AND PRACTICES

Administrative Uses

1. Teachers use network capabilities for timely, efficient, and improved communication among students, teachers, parents, administration, and others and to overcome isolation.
2. Teachers use network for submitting grades, recording attendance, sending correspondence, etc., to increase efficiency of operations.
3. Teachers use network capabilities to assess student performance, for example, by creating on-line student portfolios.

Instructional Use

1. Teachers use network capability to obtain curricula and lessons, to collaborate, to exchange materials, and to share ideas.
2. Teachers use network capabilities to engage students more directly in all aspects of their learning, for example, creating databases, collaborating, making presentations, and accessing a wide variety of resources.
3. Teachers use network capabilities to involve students in tasks and projects that are meaningful and relevant to the students' life and world.
4. Teachers use a wide variety of network capabilities and resources to build classroom activities to complement instruction and to address the diversity of interests and learning styles of their students. In such an environment, students help set their own path through the learning process.
5. Through presentations, multimedia, World Wide Web pages, etc., students reach audiences beyond the school boundaries for feedback from the community, business, parents, etc.
6. Students use networks to collaborate on projects.
7. Students use network-based projects to enhance problem-solving skills.
8. Students use networks to explore careers, training, and job opportunities.
9. Students use networks to develop specific job skills.

Professional Development

1. District maintains an on-going plan for staff development.
2. District provides professional development to all staff, including teachers, aides, substitutes, and administrators.
3. Professional development is tailored to individual needs of teachers and staff.
4. District training complements site-based training.
5. Teachers take hands-on courses on how to integrate network resources into the curriculum and instruction.
6. Teachers take hands-on courses on how to use the network infrastructure, network skills, and tools, e.g., Internet, Web browser, file transfer, etc.
7. Training can be applied by staff immediately upon returning to their sites.

8. Activities are sensitive to the non-user perspective.
9. Incentives are provided for participating in training.
10. Network capabilities are used to expand teachers' content knowledge.
11. Sources of training include building-level technology coordinators, colleagues, colleges/universities, students, self-instruction, consultants, conferences/workshops, on-line courses, parents, and community members.
12. Programs encourage staff to obtain personal computers at home.
    - District allows loans of personal computers for staff development at home.
    - District arranges low-cost financing and educational pricing.

CONCLUSIONS AND RECOMMENDATIONS:

CONCLUSIONS

In the Model Nets study we set out to study and characterize the effective use of computer networks by schools. We were especially interested in how districts enlisted computer networks to improve teaching and learning. Overall, our findings confirmed our high expectations for this group of districts, which we had selected for their pervasive use of networks. Driven by the national imperative to "wire" all schools to the information superhighway, these districts had impressive technical infrastructures that supported a wide variety of services. The rapid pace of technological change creates a challenge for school districts in planning and implementing networks, much as it challenged the design of our study. For example, the dramatic emergence of the World Wide Web offers new educational opportunities that barely existed when we began planning the study. Nonetheless, we found that these districts were exploiting these new resources. Almost all have direct access to the Internet. In many cases, these districts have enhanced and expanded the national infrastructure by providing Internet access to their communities, for example, and by creating home pages on the World Wide Web. Districts have also used networking to bring community members and other "outsiders" into the schools electronically and into the wider world of computer networking beyond the schools. Thus their local infrastructures have extended the reach of the national information infrastructure into communities.

As full-fledged participants in the so-called information revolution, districts are struggling with the same issues as business and industry. They are sorting through decisions about hardware and software platforms; about vision, planning, and policy; about learning how to access, sort, edit, and use information from networks; and about appropriate, productive, *effective* use of the technology. We found that districts use networks to increase administrative efficiency and to make district operations flow more smoothly through distribution of administrative data. For many districts, this administrative efficiency is a central tenet of their vision of network use. In the domain of teaching and learning, many districts are actively using computer networks in their classrooms. We found that students, teachers, administrators, and other school staff are accessing information, using e-mail, publishing World Wide Web home pages, and otherwise communicating with colleagues, students, their communities, and others beyond their school. This network-facilitated communication is local, national, and international. Networks also give community members, parents, business people, and others a new and convenient means of playing a role in the schools. As a communication medium, networks seemed to have opened up new relationships and invigorated old ones. The heavy reliance on e-mail by school staff in our study confirmed the often-voiced need for better communication by school staff among colleagues and with parents.

Networks appear to spark motivation among teachers and students. Teachers report increased interest in learning among students. We found that network-based on-line information searches and e-mail based communication saved time and made it easy for teachers and students to reach beyond the school building for resources, ideas, information, and camaraderie. As a learning tool, networks appear to be a vast electronic library and e-mail system that provides access to information and to other people not otherwise available. Especially for students and teachers in

rural, isolated, or impoverished areas, this may be an invaluable benefit. We also found that students are developing workforce readiness skills by performing varied tasks related to storing, retrieving, and manipulating information on networks. Yet we also found that teachers felt networks had less impact on students in higher grades, especially high school students compared to elementary students. But in general, through the site visits and teacher surveys we found network practices that followed a student-centered, discovery-based model of learning. These are the practices upon which we based the Guidelines to Implementing Effective Computer Networks. However, despite the frequently lofty claims about the impact of networking on students and the obvious evangelizing of many of our interview subjects, we did not find practices for evaluating the impact of computer networks on student learning or achievement. Few of the districts that we studied had plans to evaluate their networks at all. Apparently, few funding agencies or state education agencies required evaluations. We also found very little evidence of professional development for teachers in how to plan curriculum that incorporates student use of computer networks as an integral part of student learning, though many teachers expressed the need for this kind of training.

It is appropriate here to remember a few findings of the study. First, although schools consistently expressed concern about the lack of long-term, stable funding and policy for networks, none of our research suggests inadequacy in the national information infrastructure or in the technology available to (or affordable by) schools to support teaching and learning. Second, many of the districts originally installed their networks to meet perceived administrative needs, then expanded them or created separate networks to support teaching and learning. Finally, only 1 in 5 districts assessed their needs before planning and implementing a computer network, which suggests that the districts deemed the networks *a priori* as necessary or a "good thing" for educational applications. However, because local needs were not studied and explicitly identified and because districts have not evaluated the instructional effectiveness of their networks, we conclude that the common network activities do not *necessarily* meet the specific needs of students in a particular district.

Our research leads us to believe that in the area of networking, most districts have yet to forge the imaginative links among student needs, instructional use, and technological capabilities. Therefore, schools use networks for teaching and learning in the most obvious or pedestrian ways, with scant attention paid to their effectiveness. But districts face a daunting task. In light of their own educational goals and assessments of student need, they must both master the technical issues of implementing a network and grasp the pedagogical opportunities unleashed by the technology. Creative imagination is often intimately linked to one's skills with the tools at hand. To imagine and then implement the *most* effective use of computer networking, districts may find they need to engage in a recursive process of learning about the technology, planning, implementing, learning more, planning again, and so on. Like everyone else, they may find it hard to identify the gaps in their knowledge about networking until they learn more about it, then try something new, then evaluate their results. The rapid pace of technological change only exacerbates the problem. It may take a district a few years of this learning process before they begin to develop innovative applications of networking to meet the particular needs of their students.

In general we did not find that educational goals shaped the planning and implementation of networks. And given that one fifth of the teachers in our survey had *never used* a network, the technology clearly is not yet integral to their teaching. Only when particular educational goals require the instructional deployment of a computer network can it be considered integral to teaching and learning. Then in the domain of teaching and learning, the network will become a vital tool in helping the district reach its educational goals.

Our findings in the area of technical infrastructure underscore the need for professional development. Given that we sought districts that were already using networks, we were surprised by the wide variance in and use of their infrastructures. Some districts were just getting started. Others had been using their networks for a few years but had weak systems, such as LANs that were not connected to district WANs or vice versa. We also found districts with less than 56 Kbps bandwidth, which limited the range of services they could exploit on their networks. Yet in most cases, districts appeared to be constrained not by hardware or software, but by their teachers' knowledge of how to get the most out of them. The pedagogical uses of the networks did not reflect the sophistication of the infrastructure. Classroom applications of networks were much the same across all districts, whether they had a state-of-the-art network with full-motion, real-time video transmission capability, or borderline obsolete network without even Microsoft Windows capability. Again, on-line information retrieval and communication were the dominant uses by both teachers and students, activities that can be accomplished at least marginally with low bandwidth. In the study, we found little professional development to educate school staff in the skills necessary for integrating the technology with curricular goals and objectives or classroom activities. Some teachers even pointed out this failing. Thus some of the more technologically sophisticated infrastructures far exceed the current ability of teachers to exploit them. As a learning tool, computer networks are only as good as the understanding of how to enlist them for *learning* purposes.

In this context, where infrastructure often exceeds the ability of districts to use it, network "scale-up" may best be accomplished by first getting all teachers on-line and by increasing their skills. Investing in their training—both in hardware and software use and in how to use the network to improve their teaching—will allow them to fully exploit network resources and capabilities and to "work smarter" with what they already have. Such professional development can also support the planning process by exposing school staff to the new horizons offered by the technology.

Thus we are left with a few critical questions that demand further research: Do computer networks improve student achievement? If so, how do they improve it? Do computer networks foster improvements in teaching? Again, if so, how do they foster these improvements? Answering these questions will help schools decide how to best use their limited resources to make the most of computer networks. Given the levels of funding and human energy currently pouring into the implementation of computer networks in schools, these questions warrant conclusive responses based on sound research.

RECOMMENDATIONS

Based on what we have learned from the Model Nets study, we have developed recommendations for additional research and for state and federal agencies that support computer networking in schools. The recommendations are listed below by category.

Recommendations for Further Research

Additional research is required to deepen the understanding of networking in schools, by

- investigating the effect of networking on student achievement
- conducting a longitudinal study of computer networks in schools by revisiting in 3-5 years a sample of the districts studied under Model Nets

Recommendations to Funding and Policy-Making Agencies

Federal and state funding agencies should support school-district computer networking projects by providing long-term, stable funding for

- computer network projects that support local, district, and state education goals
- school district networks that are widely accessible and used by students, teachers, parents, school staff, and community members at large
- professional development for district and school staff
- participation of technical experts to plan, design, implement, and maintain computer networks
- implementation of districtwide WANs and school LANs with voice, video, and data capability
- high school networking projects or those districts that provide articulation of networking throughout grades K–12